ARPA-E Project Selections – TECHNICAL DESCRIPTIONS

July 12, 2010

These projects have been selected for negotiation of awards; final award amounts may vary.

Lead Research Organization (Partner Organizations)	**Amount**	**Lead Organization Location** (City, State)	***Technology Focus – Application: Project Title*** **Project Description**
1) Agile Delivery of Electrical Power Technology (ADEPT)			
Arkansas Power Electronics International, Inc. (University of Arkansas, ORNL, Toyota, Cree)	$3,914,554	Fayetteville, AR	*Circuit Topology/Switches - Automobiles: Low-Cost, Highly-Integrated Silicon Carbide (SiC) Multichip Power Modules (MCPMs) for Plug-In Hybrid* Charging modules for plug-in hybrid electric vehicles (PHEVs) are grid-tie power electronics. As electric vehicles become more prevalent, higher power levels will become necessary to enable rapid battery charging. This program will develop and demonstrate a transformational, highly-efficient, ultra-compact, and low-cost silicon carbide PHEV charger that will have a disruptive impact on electrical power conversion technology.
Case Western Reserve University (G&S Titanium, Evans Capacitor Company)	$2,254,017	Cleveland, OH	*Capacitors - Automobiles: High-Power Titanate Capacitor for Power Electronics* This project will develop novel capacitors for power electronics in the hybrid electric vehicle and consumer electronics markets. The capacitors will involve a new material, electrolytic titanate, and will include built-in spontaneous self-repair. Thin spine electrodes will enable low series resistance and inductance, as well as high power density. This will result in large improvements in energy density over state of the art capacitors, as well as improvements in high frequency use, and price per kW. The market for capacitors in power applications is $1.6 billion per year.
Cree, Inc. (Powerex, North Carolina State, ABB, Naval Research Lab)	$3,736,291	Durham, NC	*Switches - Transmission: 15 kV SiC IGBT Power Modules for Grid Scale Power Conversion* The purpose of this program is to demonstrate a highly efficient transformerless intelligent power substation (TIPS) that can help manage a new Smart Grid by providing consistent electrical energy from renewable sources. These novel TIPS will be enabled by the development of high-voltage Silicon Carbide (SiC) insulated gate bipolar transistors, semiconductor-based power switches. TIPS can replace present distribution transformers, which are heavy (8000lb) with a much smaller (100lbs) and more efficient (98%) transformer.

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CUNY Energy Institute (Columbia University, UC Berkeley)	$1,568,330	New York, NY	*Capacitors - Lighting: Metacapacitors* This project will develop novel nanoscale-engineered dielectrics for a new breed of capacitors that enable low-cost, efficient inverters for small grid-tied photovoltaics and solid-state lighting. The thin film capacitor structures can be printed for high throughput, low-cost microfabrication. Electronic switches and power electronic control integrated circuits are bonded onto and sealed into these capacitor films to form Metacapacitors. The resulting Metacapacitors are a high power density, low loss technology platform for load management and power conversion.
GE Global Research (Dartmouth University)	$949,545	Niskayuna, NY	*Magnetics - Photovoltaics: Nanostructured Scalable Thick-Film Magnetics* The goal of this project is to develop a prototype power magnetic component with extremely high efficiency (97%) for kW-level applications. It will develop a thick-film magnetic technology to enable advanced core materials for a new generation of compact, efficient, low-cost power converters for photovoltaics. To develop the novel nanostructured, millimeter-scale magnetic materials, an advanced physical vapor deposition process will be used that is both scalable and low-cost.
GeneSiC Semiconductor (Dow Corning, University of Illinois-Chicago, Bonneville Power Administration, Sandia National Labs)	$2,450,000	Dulles, VA	*Switches - Transmission: Monolithic Silicon Carbide Anode Switched Thyristor for Medium Voltage Power Conversion* This project will develop revolutionary semiconductor technology that will allow efficient processing of Megawatts of electrical power with digital precision. Specifically, Silicon Carbide (SiC) Anode Switched Thyristors will be developed and will enable precise reactive compensation, control, and tuning of all circuits, and unprecedented increases in the efficiency and cost-effectiveness of the electricity infrastructure.
Georgia Tech Research Corporation (National Semiconductor)	$999,017	Atlanta, GA	*Magnetics - Consumer Electronics: Highly Laminated, High Saturation Flux Density Magnetic Cores for On-Chip Inductors in Power Converter Applications* The goal of this project is to greatly reduce the size and cost, and increase the efficiency of laptop power supplies, and other chargers and components used to power consumer electronics. It will do so through the development of low loss, high magnetic flux density, and metallic magnetic materials for single-chip power converters. New manufacturing technologies are employed to create stacked, extremely thin plate cores of iron alloys, forming them into inductors and transformers, and integrating them with specialized electronic components to make very small scale power converters.

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Georgia Tech Research Corporation	$981,619	Atlanta, GA	*Circuit Topology/Switches - Transmission: Dynamic Control of Grid Assets Using Direct AC Converter Cells* Technology developed in this program will enable dramatic cost reductions in smart grid implementation and allow increased penetration of renewable energy resources by reducing transmission and distribution upgrade costs by up to 80%. A utility scale, low-cost Imputed DC Link Converter cell will be developed to realize direct and dynamic control of existing grid assets. The project will involve several developments – a new converter topology that achieves an AC/AC function using minimal number of switches, and the elimination of DC energy storage in the system.
HRL Laboratories, LLC (GM, Va Polytech, ORNL, Teledyne)	$5,058,803	Malibu, CA	*Switches – Automobiles: Gallium-Nitride Switch Technology for Bi-directional Battery-to-Grid Charger Applications* The purpose of the project is to develop efficient, high power, and cost effective power converters with application to the automotive sector. More specifically, it will utilize high voltage Gallium Nitride (GaN) on low cost silicon substrate switches operating at megahertz frequencies. The innovative design will result in a battery-to-grid bi-directional charger that enables efficient, cost effective power management focusing on grid-interactive distributed energy systems for the automotive sector.
Massachusetts Institute of Technology (Dartmouth, Georgia Institute of Tech, U Penn, OnChip Power)	$4,414,009	Cambridge, MA	*Switches/Magnetics - Lighting: Advanced Technologies for Integrated Power Electronics* This project targets radical improvements in the size, integration and performance of power electronics for high-efficiency solid-state lighting (SSL) with a focus on circuits for interfacing with grid-scale voltages (>100 V) at power levels of 10 – 100W. Specifically it will develop Gallium Nitride on Silicon (GaN-on-Si) power devices, nano-structured magnetic materials and microfabricated magnetic components, and very-high-frequency power conversion circuits. Additional focus will be on the co-optimization of these novel elements to achieve high-performance.
Teledyne Scientific & Imaging (Flextronics, RPI, Teledyne Lighting & Display Products, Anthony International)	$3,439,494	Thousand Oaks, CA	*Magnetics/Switches - Lighting: Integrated Power Chip Converter for Solid State Lighting* This project will develop a transformational 25 watt AC-DC power supply on a chip intended to impact the adoption of white Solid-State Lighting (SSL). The power supply will be the result of novel high energy density chip-scale capacitors; low loss, and low cost magnetics at megahertz frequencies; and chip-scale integration technologies with lower manufacturing and assembly costs. It will reduce the lifecycle cost of SSL and accelerate its adoption. Widespread use of SSL will save energy for lighting needs in the commercial, residential,

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			infrastructure, and industrial sectors.
Transphorm Inc (Kroko, Evans Analytical, UCSB Nanotech, Consultant Magnetics, Stacia Keller)	$2,950,000	Goleta, CA	*Switches - Motors: High Performance GaN HEMT Modules for Agile Power Electronics* This project seeks to enable compact motor drives and grid-tied inverters operating at high power (3-10 kW) with efficiency greater than 96%. It will develop the first hybrid multichip power modules for inverters and converters operating at high frequency (1 megahertz), using low-loss ultra-fast GaN-on-silicon power switches that are normally in off mode. This vertically integrated approach realizes cost savings at many levels in power electronic systems, to produce unprecedented energy savings at reduced systems cost. The result would foster wide deployment of compact, high efficiency variable speed drives, which could be embedded in new motors or even retrofitted to older generation motors.
Virginia Tech (U of Florida, UT-Dallas)	$900,000	Blacksburg, VA	*Magnetics/Capacitors - Consumer Electronics: Isolated Converter with Integrated Passives and Low Material Stress* This project will develop a monolithic power converter to be used in efficient power adapters for mobile applications, such as netbooks. The chip converter will include the integration of a transformer, ultra-high-density capacitors, and a nano-magnetic material dispensable with high precision by low-cost inkjet printing. The magnetic structure, with a 3X improvement in energy storage, is introduced to keep the transformer volume at a minimum. The resulting highly efficient (>90%) converters with high power density will reduce the 15 tera-watt-hours of energy consumed by notebooks and netbooks annually.
Virginia Tech (University of Delaware, International Rectifier)	$983,000	Blacksburg, VA	*Magnetics/Switches - Consumer Electronics: Power Supplies on a Chip (PSOC)* This project is expected to result in a technology to replace the current power management voltage regulators for powering the future generations of microprocessors, graphic cards and memory devices. A 3D integrated power supply on chip (PSOC) will be developed using chip-scale integration of a new generation of Gallium nitride (GaN) on Silicon devices with new high frequency soft magnetic material. By significantly reducing the size of magnetic components and eliminating most of the bulk capacitors, this high density PSOC is expected to free up 90% of space on mother boards currently occupied by voltage regulators (25% of the motherboard).

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2) Building Energy Efficiency Through Innovative Thermodevices (BEET-IT)			
ADMA (Pacific Northwest National Laboratory, Texas Engineering Experiment Station-Texas A&M University)	$3,269,965	Hudson, OH	*Dehumidification: High-Efficiency, on-Line Membrane Air Dehumidifier Enabling Sensible Cooling for Warm and Humid Climates* In warm and humid climates efficiency of air conditioning decreases significantly in removing the moisture out of the air. This ADMA-led team will develop a dehumidification membrane that can selectively sieve out water molecules from the humid air stream that flows over it while leaving behind the oxygen and nitrogen molecules. PNNL will make this membrane by deposition of a very thin layer of a special class of ceramic materials, known as a molecular sieve, on the surface of a porous metal sheet about the thickness of a piece of paper. The membrane allows water vapor permeation at very high flux while blocking air molecules. ADMA will use its expertise to develop roll-to-roll manufacturing processes to fabricate the product at a low cost. If successful, this technology will significantly reduce energy consumption for air cooling in hot and humid climates and reduce future CO_2 emission growth from the HVAC sector.
Architectural Applications (Membrane Technology and Research, Inc., Lawrence Berkeley National Laboratory)	$458,265	Portland, OR	*Dehumidification: Innovative Building-Integrated Ventilation Enthalpy Recovery* Architectural Applications and team members will develop a membrane-based enthalpy exchanger that captures the cooling and dehumidifying benefits from building exhausted air and recycles it to partially condition incoming fresh air. Contrary to conventional enthalpy recovery systems, this system is located within the depth of the building enclosure and can have a large surface area, with very slow air flow over it, resulting in high efficiency enthalpy recovery with little added fan power. Its integration into the wall will reduce demand on and size of the building air conditioning equipment. It will also work well for existing building renovations. The system promises a Coefficient of Performance increase of 25 - 40% compared to conventional air conditioning systems.
Astronautics Corporation of America	$2,889,839	Milwaukee, WI	*Solid State Cooling: An Efficient, Green Compact Cooling System Using Magnetic Refrigeration.* Traditional refrigeration systems use liquid based refrigerants which have global warming potential (GWP) more than 1000 times of CO_2. Astronautics Corporation of America (ACA) proposes to construct a solid state magnetic refrigeration (MR) cooling system to achieve significant energy efficiency and reduce system operating costs compared to conventional vapor compression systems. The MR system does not use

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			greenhouse or ozone-depleting gases and has a GWP of 0. ACA will implement a theoretically modeled design using the rotating bed architecture, where a wheel of 16 beds rotates through a gap of a magnet assembly. Each bed will contain 14 layers of LaFeSiH in a connected-particle regenerator. This technology can reduce cooling power from 3.5kW to 1.0kW with minimal impact on efficiency which results in high part-load efficiency. It will also achieve substantial system size reduction using magnetocaloric materials with larger entropy change and sharper transitions.
Battelle Memorial Institute, Corporate Operations (Dynamic Solutions, LLC)	$401,654	Columbus, OH	*Vapor Absorption/Adsorption: Cascade Reverse Osmosis and the Absorption Osmosis Cycle* More than 90% of cooling is provided by vapor compression based systems which use mechanical compressors. Battelle proposes to demonstrate Cascade Reverse Osmosis (Cascade RO) technology to separate refrigerant water from an absorbing salt solution for re-use in the cooling cycle for refrigeration. This project will replace compression of refrigerant vapor and/or thermal distillation of refrigerant in a traditional refrigeration absorption cycle with a more efficient liquid pumping and membrane separation process using currently-available reverse-osmosis membranes. Modeling has shown that the Absorption Osmosis (AO) Cycle can be 86% more efficient than a vapor-compression cycle, which will result in significant energy and cost savings.
Counseling & Consulting Associates (Flometrics, On Target Design)	$400,000	San Diego, CA	*Gas Cycles: Centrifugal Air Cycle Air Conditioning System* Counseling and Consulting Associates proposes to use air as the refrigerant and proprietary technology to boost the performance of air conditioning systems. Using air as a refrigerant, outside air is compressed (making it hot), passed through a heat exchanger located outside of the building to cool it, then decompressed to supply cool air to the inside of the building. A novel technology will be used to boost the performance of the heat exchanger. By using air, the second heat exchanger in a traditional air conditioning system is not required and no CFC or HCFC gases are used.
Georgia Tech Research Corporation (Stone Mountain Technologies, Inc., ARS Solutions, LLC)	$2,399,842	Atlanta, GA	*Vapor Absorption/Adsorption: Modular Thermal Hub for Building Cooling, Heating and Water Heating* This team led by Georgia Tech will develop a thermally activated hub for modular, scalable, distributed cooling and heating in buildings that can run on thermal energy from combustion, low-grade waste heat or solar energy. This project leverages several-fold enhancements in coupled heat and mass transfer made possible through microscale passages. Cooling capacities ranging from hundreds to tens of thousands of watts are possible by scaling-up component geometry. The mass-producible miniaturized systems can be packed as

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			monolithic full-system packages or discrete, distributed hydronically coupled components for both residential and commercial building applications. The reversible operation enables space cooling and heating, coupled with water heating, to yield equivalent electrical energy-based COPs of 2.5-8.3, equating to a primary energy use reduction of 51% while using fluids with zero Global Warming Potential.
Infinia Corporation (Heat Transfer Technologies, Enertron, Barry Penswick)	$3,000,617	Kennewick, WA	*Gas Cycles: Stirling Air Conditioner (StAC) for Compact Cooling* Infinia proposes to develop and demonstrate a prototype Stirling Air Conditioner (StAC) that combines the Stirling cycle with innovative heat transfer coupling to produce improvements in compact cooling. This project will use no greenhouse gases, can achieve a system COP greater than 4, and is cost effectively mass-producible with a system lifetime exceeding that of traditional vapor compression systems. Other benefits include the ability to operate over a wide range of environmental temperatures and humidity conditions with high efficiency, the ability to modulate output with variable speed fans, and the ability to scale to various sizes to meet market needs.
Material Methods LLC VIT LLC	$399,800	Irvine, CA	*Gas Cycles: Phononic Heat Pump* This team led by Material Methods LLC will demonstrate a refrigerator that pumps heat using sound waves. Low cost and high reliability result from high thermal efficiency and mechanical simplicity with no linkages, no exotic materials, and simple construction. The working fluid is environmentally safe and friendly.
Pacific Northwest National Laboratory (Power Partners, Inc., Arkema)	$2,541,952	Richland, WA	*Vapor Absorption/Adsorption: High Efficiency Adsorption Chilling Using Novel Metal Organic Heat Carriers* This PNNL-led team will develop a new class of adsorption chiller that takes advantage of the tunable binding energy available with metal organic heat carrier (MOHC) sorbents, a nanoporous structured material, and select refrigerants to achieve high efficiency in commercial heating, ventilation, air conditioning and refrigeration systems. This project will develop a 5-ton minimum cooling capacity prototype unit designed, assembled and tested with a target thermal energy COP of 1.5 or higher; a breakthrough in adsorption chiller technology performance.
Sheetak Inc.	$563,303	Austin, TX	*Solid State Cooling: Non-Equilibrium Asymmetric Thermoelectric (NEAT)* Sheetak proposes to develop a new thermoelectric material system known as Non-Equilibrium Asymmetric Thermoelectric (NEAT), which can achieve high performance in solid state refrigeration compressors. Sheetak plans to improve refrigeration engine efficiency to surpass that of current

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			compressor systems using its understanding of thermoelectric behavior, and electrical and thermal conductivity. Compared to a traditional compressor system with an evaporator, condenser and expansion valve, Sheetak product will be a complete system that produces cold air without using fluids with Global Warming Potential and with decreased energy demands.
The Pennsylvania State University (ThermoAcoustics Corporation, Heatcraft Worldwide Refrigeration)	$2,988,720	State College, PA	*Gas Cycles: One-ton (3.5 kW thermal) Thermoacoustic Air Conditioner* This team led by Penn State University proposes a thermoacoustic-Stirling chiller system to produce a 1-ton air conditioning unit that uses high-amplitude sound and helium gas to recycle acoustical power for cooling. This project will scale up an ice cream chiller built for Ben & Jerry's that combined the acoustic power produced by high-efficiency moving-magnet linear motor with recycled power to produce useful cooling in a "bellows bounce" thermoacoustic chiller. This project will not use exotic materials that increase cost or reciprocating seals that limit service life.
The Regents of the University of California, Los Angeles	$520,547	Los Angeles, CA	*Solid State Cooling: Compact MEMS Electrocaloric Cooling Module* UCLA will develop a novel solid-state cooling technology to translate a recent scientific discovery of the enhanced electrocaloric effect into commercially viable compact cooling systems. UCLA will utilize micro/nano-scale manufacturing technologies to extend the performance and reliability of the cooling module, develop physical models to identify optimal designs of key components, exploit nanoscale phenomena to develop materials with tunable thermal and thermomechanical properties, develop reliable thermal interfaces to achieve cooling power densities, and use precision micro-fabrication technologies to enable design and manufacture of reliable mechanical components. This technology will develop highly efficient cooling technology that will reduce energy consumption in building space cooling and avoid the use of refrigerants.
United Technologies Research Center	$2,855,795	East Hartford, CT	*Mechanical Vapor Compression: Water-Based HVAC System* UTRC proposes to develop a 1-ton capacity air conditioning system with a COP of 4 or greater with water as a refrigerant and utilizing a novel type of supersonic compression that enables high-compression ratios in a single stage, thus, enabling lower cost than existing designs. Several heat exchanger options will be explored including direct-contact with secondary circulating loops. Water is a natural refrigerant with zero global warming potential, which will reduce the use of global warming gases.

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United Technologies Research Center (Pall Corporation, Polymer Science Associates, New Jersey Institute of Technology)	$3,098,765	East Hartford, CT	*Vapor Absorption/Adsorption: Nano-Engineered Porous Hollow Fiber Membrane-Based Conditioning System* UTRC and Pall Corporation will develop and demonstrate an air conditioning system optimized for use in warm and humid climates with an efficiency of at least 50% greater than conventional air conditioning units. UTRC will integrate a liquid desiccant and a vapor compression cycle to overcome current barriers of liquid desiccant systems: corrosion and carryover. The concept is projected to obtain a primary COP of 1.13 compared to 0.75 for conventional air conditioning systems at the FOA system cost target of $1,500/ton for new systems and $1,000/ton for retrofits. The project includes identifying and characterizing membrane materials and structures, designing the heat and mass transfer modules required to provide heat and humidity removal, and developing the components and controls required for successful integration.
University of Florida (b2u Solar, Inc., Wolverine Tube, Inc.)	$1,000,000	Gainesville, FL	*Vapor Absorption/Adsorption: A New Generation Solar and Waste Heat Power Absorption Chiller* This project will develop a next generation solar powered absorption chiller that is an order of magnitude smaller than the existing systems with a significantly reduced cost. Development of a next generation compact and inexpensive solar and waste heat powered absorption refrigeration systems (ARSs) with substantially better performance than the existing technology will greatly reduce HVAC energy consumption and carbon emission. The ARS fluids considered have no Global Warming Potential (GWP).
University of Maryland (GE Global Research, Pacific Northwest National Laboratory)	$500,001	College Park, MD	*Solid State Cooling: Thermoelastic Cooling* This team led by University of Maryland proposes to demonstrate a 0.01-ton prototype for cooling based on thermoelastic shape memory alloys, with the goal of establishing the commercial viability of thermoelastic cooling (TC). TC systems COP can be 175% more than that of conventional vapor compression (VC) technology, which are currently used for 90% of US space cooling. Replacement of VC technology with TC will reduce US annual primary electricity consumption by up to 2.2. quads per year, the equivalent of 250 metric tons per year of CO2 emissions. TC refrigerant is a solid state technology, which eliminates the need for high global warming potential refrigerants and requires a smaller operational footprint.
University of Notre Dame (Dometic LLC)	$2,817,926	Notre Dame, IN	*Mechanical Vapor Compression: Compact, Efficient Air Conditioning with Ionic Liquid Based Refrigerants* Global warming potential (GWP) of current refrigerants is more than 1000 times the GWP of CO2. This makes CO2 very attractive as referigerants. However, CO2 based refrigeration

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			systems require approximately 100 times higher pressure than atmospheric pressure for operation. The team led by University of Notre Dame will develop a co-fluid Vapor Compression (VC) cycle based on CO2 and Ionic Liquids (ILs). This will allow to run the CO2 VC system with a co-fluid that reversibly absorbs the CO2, thus greatly reducing the pressure requirements. The project will extend system models to identify the characteristics of an optimal IL co-fluid, use atomistic simulation and experimentation to discover these fluids, and ultimately demonstrate an operating CO2-IL system with efficiency well beyond that of existing ACs using HFC-410a refrigerants systems.
3) Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)			
ABB Inc (SuperPower Inc., Brookhaven National Lab)	$4,200,000	Cary, NC	*Superconducting Magnetic Energy Storage (SMES): Superconducting Magnet Energy Storage System with Direct Power Electronics Interface* ABB will lead a team in the development of an advanced superconducting magnetic energy storage (SMES) system that will store significantly more energy than current SMES at a fraction of the cost. In this project, the team will develop a 20 kW ultra-high field (UHF) SMES system with a capacity of 3.4 MJ, a field of up to 30 T at 4.2 K, and roundtrip efficiency in excess of 85%. The system will have the conventional advantages of SMES, namely instantaneous dynamic response and nearly infinite cycle life, but with costs that approach or potentially are less than those of lead-acid batteries. To achieve these goals, the performance of each of the individual subsystems that compound the proposed SMES system will be propelled far beyond the present state-of-the-art. The result will advance SMES from a high-cost solution for delivering short bursts of energy to a technology that is cost competitive for delivering megawatt hours of stored electricity to address the renewables ramping challenge.
Beacon Power Corporation (Imlach Consulting Engineering, IONICORP)	$2,250,000	Tyngsboro, MA	*Flywheel: Development of a 100 kWh/100 kW Flywheel Energy Storage Module* Beacon Power will lead a team in developing a next generation flywheel energy-storage module that stores four times the energy at 1/8 the cost-per-energy of the lowest cost state-of-the-art flywheels. The proposed 100kW, 100kWh system will use a “flying ring”: a lightweight hoop of co-mingled fiber composite with bonded magnetic materials mounted on the structure. This configuration eliminates the central shaft and hub allowing full utilization of the composite properties, thereby reducing cost and increasing energy density to 76Wh/kg. This design will be capable of very high cycling

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			(>40,000 full charge/discharge cycles) and will have a 20 year life, making it ideal to simultaneously address multiple grid-scale energy storage applications, including frequency regulation as well as emerging for ramping power to firm intermittent renewable generation.
Boeing	$2,264,136	Huntington Beach, CA	*Flywheel: Low-Cost, High-Energy Density Flywheel Storage Grid Demonstration* In this project, Boeing will use advanced fiber technology to develop a low-cost, extremely high energy-density, high-efficiency flywheel technology for energy-storage. This project will increase flywheel energy density to allow for the practical use of this technology in longer-duration applications including renewable energy ramping on the electric power grid. To increase energy density, Boeing will develop a new proprietary fiber that will enable high rotor tip speeds. If successful in this high-risk technology development program, a flywheel systems will be scalable to a utility-size unit (~100 kWh) and amenable to factory production to achieve low cost ($100/kWh).
CUNY Energy Institute (Rechargeable Battery Corporation)	$3,000,000	New York, NY	*Battery: Low-cost Grid-Scale Electrical Storage using a Flow-Assisted Rechargeable Zinc-Manganese Oxide Battery* In this project, the CUNY Energy Institute, in partnership with Rechargeable Battery Corporation (RBC) and Ultralife Corporation, will develop and construct a water-based flow-assisted battery for grid-scale energy storage. This novel battery starts with the same low-cost materials found in disposable consumer-grade alkaline batteries, namely zinc and manganese dioxide, and then transforms the chemistry into a long-lasting, fully-rechargeable system. CUNY has initially demonstrated a zinc and nickel oxide battery that proves the basic science behind the concept of flow-assist for enabling zinc to repeatedly store electrical energy. In this project, the team will push this approach in a new direction by replacing nickel with reversible electrodes by leveraging key material innovations by RBC. The result of this effort will be a 25kW rechargeable system that lasts for 5,000 cycles, costs under $100/kWh, and shows strong potential for scaling to megawatt-hour levels in grid-scale electric energy storage applications.
Fluidic Energy, Inc.	$3,000,000	Scottsdale, AZ	*Battery: Enhanced Metal-Air Energy Storage System with Advanced Grid-Interoperable Power Electronics Enabling Scalability and Ultra-Low Cost* Fluidic Energy, in cooperation with partners Satcon and Chevron Energy Solutions, proposes a high-risk-reward program to develop a novel, low-cost, battery for intermittent renewable energy ramp support on the electric power grid. The proposed advanced multi-function energy storage (AMES)

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			prototype is highly scalable and will provide multiple modes of operation. The AMES device will be built around highly-efficient battery chemistry, but will use novel approaches to address traditional challenges for grid storage deployment, including limited rechargeability, low power density, and poor roundtrip efficiency. The AMES device will provide energy storage at low cost, in part by developing domestically-sourceable and geologically abundant active materials in an advanced battery chemistry. The system will be scalable to the megawatt-hour levels necessary for grid-scale energy storage.
General Atomics (UC San Diego)	$1,986,308	San Diego, CA	*Flow Battery: GRIDS Soluble Lead Flow Battery Technology* General Atomics and the University of California San Diego will develop a novel flow battery technology based on lead-acid chemistry that significantly reduces costs and extends battery life. For a century, the lead-acid battery has been used in a variety of energy storage applications. While few battery technologies can match lead-acid's combination of low-cost, high-efficiency, safety, and proven reliability, the lead-acid chemistry inherently suffers from poor cycle life when deeply discharged as well as poor electrochemical materials utilization. The proposed flow battery will use novel electrode materials that greatly increase the surface area available for chemical reactions, minimizing the amount of excess lead in the battery. In addition, the electrodes will resist the corrosion that typically limits the cycle life of conventional lead acid batteries. These innovations will result in a battery that easily can be scaled for grid-scale energy storage, but which costs less than existing technologies to accelerate the adoption and integration or renewable energy sources.
General Compression	$750,000	Newton, MA	*Compressed Air Energy Storage (CAES): Fuel-Free, Ubiquitous, Compressed Air Energy Storage and Power Conditioning* General Compression will lead a team to develop a novel compressed air energy storage process (GCAES™) that is highly efficient and requires no fossil fuel. In this project, a team of industry and academic researchers will investigate near-isothermal CAES, which offers the potential of round-trip electrical efficiency up to 75% and a response time of less than one second. Unlike conventional CAES installations, no fuel will be burned in the expansion stage of the proposed process, dramatically reducing emissions and operating costs. If successful, this innovative compressed air energy storage technology could accelerate the integration of renewable electricity resources, particularly wind, into the grid.

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Lawrence Berkeley National Laboratory (DuPont, Bosch, 3M, and Proton Energy)	$1,592,730	Berkeley, CA	*Flow Battery: Hydrogen-Bromine Flow Batteries for Grid-Scale Energy Storage* Lawrence Berkeley National Laboratory and its team of industrial partners (DuPont, Bosch, 3M, and Proton Energy) will develop a hydrogen-bromine (H_2-Br_2) flow-battery system for grid applications. H-Br cells use two highly reversible and kinetically-favored electrodes to provide high round-trip efficiency. In addition, the proposed technology is expected to offer high power capabilities, thereby reducing the cost of stack components. The H-Br system promises to meet the most stringent demands of costs, performance, lifetimes, and safety. To solve these technical challenges in this project, the LBNL team will apply novel technical approaches to deliver a proof-of-concept cell that will demonstrate the potential of this chemistry in grid-scale energy storage applications.
Primus Power	$2,000,000	Alameda, CA	*Flow Battery: Low-Cost, High Performance 50 Year Electrodes* Primus Power will develop an extremely durable, highly active, conductive, and inexpensive metal electrode for flow batteries. Flow batteries are ideal for bulk energy storage applications, but are often limited by the high cost and poor durability of the carbon materials used in the battery electrodes. In this project, Primus Power will leverage processes common in other chemical manufacturing industries to develop novel, low-cost metallic flow battery electrodes. In addition, the team will develop a production process for the metal electrode by taking advantage of high volume processes used in the metals industry. Together, the low cost electrode and volume manufacturing process will result in a significant decrease in energy storage costs for the proposed flow battery technology, while simultaneously increasing the power density of the system. This project will yield a novel flow battery system that will provide scalable, low-cost energy storage that is ideally-suited for addressing the renewable ramping challenge.
Proton Energy (Penn State University)	$2,148,719	Wallingford, CT	*Fuel Cell: Transformative Renewable Energy Storage Devices Based on Neutral* Proton Energy and Penn State University will develop an advanced electrochemical energy storage device that incorporates a regenerative electrolyzer and fuel cell (REFC) and an alkaline membrane. Many fuel cells rely on acidic membranes which require costly noble metal catalysts and semi-precious metal components inside the cell stack to maintain conductivity. Transitioning to an alkaline membrane in the proposed REFC will eliminate the highest-cost materials and enable higher efficiency through reductions in current density. In this project, an inexpensive, alkaline membrane will be developed and then utilized in a 20kW reversible

Lead Research Organization (Partner Organizations)	**Amount**	**Lead Organization Location** (City, State)	***Technology Focus – Application: Project Title*** **Project Description**
			electrochemical advanced storage system that converts water to fuel and then back to water to for grid-level electrical energy storage.
United Technologies Research Center (University of Texas, Clipper Windpower, Pratt & Whitney, Sandia National Labs)	$3,000,000	East Hartford, CT	*Flow Battery: Transformative Electrochemical Flow Storage System (TEFSS)* United Technologies Research Center (UTRC), in partnership with the University of Texas and Sandia National Laboratory and Clipper Windpower will develop a flow battery system that uses a novel cell design to deliver 10X higher power density than current state-of-the art flow batteries. This breakthrough will enable a dramatic reduction in the size and cost of the cell-stack, which is the most expensive component of flow-battery systems. To take maximum advantage of this new cell-stack technology, a number of other innovative concepts will be incorporated into the system to transform the system to an energy-storage device with both rapid response times and long run times at rated power as needed for renewable energy support on the grid. A 20-kW advanced prototype flow battery will be developed in this program that will lay the scientific and technical foundation for development of a commercially-available grid-scale energy storage solution.
University of Southern California (Jet Propulsion Laboratory (JPL))	$1,459,324	Los Angeles, CA	*Battery: A Robust and Inexpensive Iron-Air Rechargeable Battery for Grid-Scale Energy Storage* Researchers at the University of Southern California and NASA's Jet Propulsion Laboratory will team to develop a high-performance iron-air rechargeable battery for large-scale energy storage for the integration of renewable energy sources on the electricity grid. Iron-air batteries have the potential to store large amounts of energy inexpensively since they rely on extremely low-cost active materials: iron, which is abundant at extremely low cost and oxygen which is obtained from ambient air. However, current iron-air battery technologies have suffered from low round-trip energy efficiency and poor cycle life. To overcome these challenges in this project, novel strategies will be used to address these issues, including the use of additives at the iron electrode to suppress inefficient and parasitic losses, the application of nano-structured electrodes with thin films of catalysts layers at the air electrode that reduce losses, use of a unique cathode catalyst support that resists degradation and increases battery life, and a novel technique to avoiding carbon dioxide from being absorbed into the battery electrolyte. This project will develop an iron-air proof of concept rechargeable battery, the first step in the

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			commercialization of this promising, low-cost battery chemistry.
TOTAL FUNDING	**$92,356,887**		